Timber Tests

U.S. Department of Agriculture

Forest Service

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United States Department of Agriculture,

BUREAU OF FORESTRY.

TIMBER TESTS.

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(1) WORK ACCOMPLISHED IN FORMER TESTS.

The former timber tests were begun in 1891 and discontinued in an incomplete state in 1896. The results were published by the Division of Forestry in Bulletin 8 (1893), Circular 12 (1896), Circular 15 (1897), and Circular 18 (1898), copies of which, together with the other publications relating to timber tests, accompany this circular. The work accomplished in these tests is also summarized in Johnson's "The Materials of Construction" (John Wiley & Sons, New York, 1897). The tests were organized and carried through under the supervision of the Division of Forestry, the mechanical tests being in charge of the late Prof. J. B. Johnson.

(2) OUTLINE FOR PROPOSED FUTURE WORK.

It is now intended to resume the work of timber testing and to conduct the tests on a large scale, in order that the work may eventually include all the principal merchantable species of the country. Its specific purpose is to obtain results that will be of the greatest practical value to engineers and others directly interested in the utilization of timber. The outline below is submitted for criticism, and it is hoped that a thorough and detailed discussion of the whole question may be had.

The tests as now planned will be divided into the following series:

Series I.—Tests on timber collected from the open market.

Series II.—Tests on timber collected from the forest.

Series III.—Tests to determine the effects of moisture and volatile oils on the strength of timber.

Series IV.—Tests to determine the effect of preservatives on the strength and durability of timber.

Series V.—Tests to determine the effect of kiln-drying methods.

Series VI.—Tests to determine the effect of the time-rate of application of load on the mechanical properties of timber, including impact tests.

SERIES I.

Tests on timber collected from the open market will be undertaken at once for the purpose of obtaining results of immediate practical value. The object of these tests will be to determine the strength of merchantable grades of timber in common use by engineers and manufacturers, purchased in the market under well-known market names, as, for example, "Georgia Pine," "Oregon Pine." The investigation will also be directed to the solution of questions such as the relative strength of Northern and Southern hardwoods, and the relative strength of Pacific coast and Eastern coast timber. The source of the timber will be mentioned in a general way, as "from Clinch County, Georgia" or "from Lewis County, Washington." No detailed information as to the conditions under which the timber grew can be presented.

In many cases several distinct botanical species are sold under one market name; for example, Georgia Pine may include Longleaf Pine, Cuban Pine. and even Shortleaf Pine. It was shown by the former tests made by the Division of Forestry that to distinguish such closely related species in the lumber yard was in many cases impracticable. It has been found, also, that the timber of the Southern pines can not always be identified even by microscopic examination. In this series of tests, therefore, the botanical names of species will be given only so far as practicable, and only those distinctions will be drawn which can be made by the engineer or inspector in practice.

Tests in Series I have already been commenced at the Washington laboratory, and work will be taken up at other points as soon as stations are established. Work is at present in progress at the station on the Pacific Coast, and tests will be made on Red Fir, Western Hemlock, and California Redwood.

SERIES II.

Tests on timber collected from the forest will be commenced as soon as the Bureau of Forestry is in a position to undertake the work in a thorough manner The principal merchantable timbers will be tested with reference to the conditions under which they were grown. By this method only can the relation between the strength of the timber and the locality and conditions of growth be determined. Since the timber will be collected in the forest, there will be no difficulty in determining the species.

SERIES III.

Tests to determine the effect of moisture and volatile oils on the mechanical properties of timber may be made in conjunction with one of the other series. Methods of procedure for these tests are outlined below. It is most important that this point be fully discussed.

SERIES IV.

This includes tests to determine the effect of various preservatives on the strength and durability of timber. No detailed plan of the work has yet been prepared. Suggestions for this most important investigation are particularly desired.

SERIES V.

Tests to determine the effect of kiln-drying methods.

SERIES VI.

Tests to determine the effect of rate of application of load, including impact tests. Static tests will be made at different time rates of application of loads on large timbers. Both static and impact tests will be made both on large beams and on small selected sticks, as, for instance, of the materials and sizes used in carriage manufacture.

(3) ORGANIZATION.

The work will be under the direction of the Bureau of Forestry, United States Department of Agriculture, and is at present carried on in collaboration with the Bureau of Chemistry.

Testing stations will be established at suitable points as the needs of the work require. The work of each testing station will be carried on by a trained engineer, under the supervision of the Washington laboratory, and all work in connection with the tests will be conducted in accordance with a uniform plan arranged by that laboratory.

Testing stations have already been established at Washington, D. C., at Yale University, New Haven, Conn., and at the University of California, Berkeley, Cal.

(4) METHOD OF PROCEDURE.

Before entering upon the work of timber testing the Bureau of Forestry consulted many experts and persons interested in the subject. The following detailed plan was submitted by Prof. G. Lanza, of the Massachusetts Institute of Technology:

GENERAL.

(1) All transverse tests and all tests of compression along the grain should be made upon full-sized pieces.

(2) Whatever the number of logs cut for transverse tests, the same number of similar logs should be cut for compressive tests.

(3) No specimen to be tested for transverse strength and stiffness should have a section smaller than 4 inches by 12 inches nor a span less than 14 feet.

(4) No specimen to be tested for resistance to compression along the

grain should have either dimension of its section less than 6 inches; its length should not be less than 4 diameters.

(5) Both in the case of transverse and also in that of compressive tests each log should be of sufficient length to furnish at least one specimen from the upper and one from the lower portion of the tree, besides some other pieces about 2 or 3 feet long from which to cut samples for other purposes.

(6) Other tests made should be—

(*a*) Shearing.

(*b*) Tension across the grain.

(*c*) Compression across the grain.

(7) Specimens should also be obtained from the extra pieces mentioned in (5) for examination in the botanical laboratory.

(8) In the case of the full-sized specimens the specific gravity is to be obtained by weighing and measuring the entire specimen, other means being adopted only in the cases of the specimens for shearing, for tension across the grain, and for compression across the grain.

(9) The liability of the timber to knots, cracks of any kind, and crooked grain should be studied in the laboratory as well as in the field.

(10) Investigations should, of course, be made upon the effect of the resisting properties of the timber of the following circumstances, viz: Age, rate of growth, time of felling, tapping for turpentine, location, direction of prevailing wind, and other climatic conditions. A series of tests on timber as found on the market is recommended.

(11) Photographs should be taken of all sides of the timbers and of all the sections used.

TRANSVERSE TESTS.

(1) The dimensions of these specimens should be determined mainly in the light of the usual length and cross-section dimensions of the logs from which are cut the timber of the kind under test commonly sold in the market and the dimensions of the beams ordinarily cut from these logs.

(2) The collectors should become familiar with these proportions before undertaking the work of collecting.

(3) Other considerations are the following, viz:

(*a*) The dimensions of the cross section adopted should not be so large that local crushing becomes inevitable either at the supports or at the points of application of the load. This limits the size in soft more than in hard wood.

(*b*) If feasible, it would be desirable to make a series of the tests with the heart in the interior of the beam, another with the heart on one side, and a third with the heart excluded; but at first the work would probably have to be more limited on account of the large number of specimens required.

(4) In making the tests some constant rate of increasing the load should be adopted and adhered to, and some definite times at which the micrometer or other readings required for the determination of the deflections should be taken.

(5) Throughout these tests a careful record should be kept of the percentage of moisture in the beams and a study made of the effect of different percentages of moisture upon the properties of the full-size beams.

(6) The following are two methods of procedure for making these tests, and it would seem that about one-half the tests should be made by each.

The first method is as follows:

(*a*) Measure and weigh the beam, thus determining its specific gravity in its normal condition.

(*b*) Determine deflections and sets under moderate loads, and hence compute the modulus of elasticity.

(*c*) Increase the load until fracture occurs, and thus determine the modulus of rupture.

(*d*) Weigh the beam a second time.

(*e*) Determine the percentage of moisture by drying the entire beam in the kiln until the percentage of moisture is reduced to a very small amount, weighing the beam a third time, thus determining its loss of weight, and measuring the shrinkage it has thus far undergone. Then determine the remaining moisture by drying suitably chosen sections cut from the beam.

(*f*) If instead of determining the moisture in the entire beam we desire to ascertain the percentage of moisture at the section where the fracture occurs, we can cut a suitable section from that portion and dry that section in the kiln, weighing it before and after drying.

(*g*) If, on the other hand, both the above are desired, it is easy to see how both can be obtained.

The second method is as follows:

(*a*) Measure and weigh the beam, thus determining its specific gravity in its normal condition.

(*b*) Determine deflections and sets under moderate loads, and hence compute the modulus of elasticity of the beam in its normal condition.

(*c*) Dry the beam in the kiln to a certain extent, thus reducing the amount of moisture, measuring and weighing the beam again.

(*d*) Determine deflections and sets under moderate loads, and hence compute the modulus of elasticity of the beam with the new percentage of moisture.

(*e*) Repeat the above process with as many different percentages of moisture as is desired, and finally increase the load until fracture occurs, thus determining the modulus of rupture under the special percentage of moisture then attained.

(*f*) Dry the entire beam in the kiln until the percentage of moisture is reduced to a very small amount, weighing the beam again, thus determining its loss of weight, and measuring the shrinkage it has thus far undergone, then determine the remaining moisture by drying suitably chosen sections cut from the beam.

(*g*) Having obtained the modulus of elasticity in both the wet and in what may be called the dry condition, and the modulus of rupture in the dry condition, we proceed to compute the probable modulus of rupture in the wet condition from the known modulus of elasticity.

(7) Besides the above, a large number of time tests should be made of full size beams.

TESTS OF COMPRESSION ALONG THE GRAIN.

(1) While no specimen should have a smaller section than 6 inches square, the greater number should be larger, the only upper limit to the size of section being determined by the testing machine.

(2) The attempt should be made, as far as possible, to include in the list of specimens to be tested all commercial sizes, the dimensions of the logs selected being those from which are usually sawed the wooden columns sold in the market.

(3) While the compressive strength of the timber can only be determined from specimens whose length does not exceed about 20 diameters, nevertheless a sufficient number of specimens having ratios of length to diameter between 20 and 45 should be tested to enable us, by plotting the results, to study the loss of strength due to these larger ratios of length to diameter.

(4) The greater portion of the work should be performed with specimens having a length of at least 10 feet.

(5) A study should be made of the effect of different percentages of moisture upon the strength, and also upon the rate of compression (the modulus of elasticity being determined from the latter). The procedure adopted being of a character somewhat similar to that already explained in the case of transverse strength, the details will not be given here.

(6) The deflections of the columns at various loads should be measured, although not much information of value can be expected from these deflection measurements.

TESTS OF THE RESISTANCE TO SHEARING (ALONG THE GRAIN), TO TENSION ACROSS THE GRAIN, AND TO COMPRESSION ACROSS THE GRAIN.

(1) In the tests for shearing, the specimens used and the methods adopted should be such as to avoid as far as possible any bending action.

(2) In the tests of tension across the grain, the form of specimen chosen and the method of testing should be such as to insure a uniform distribution of the stress across the specimen.

(3) In case of the compression across the grain, a considerable series of ratios of length to diameter should be used, finally reducing it to such an extent that a maximum load on the testing machine is no longer obtained. In this work the proportions occurring in practical cases should of course be included.

COLLECTING THE LOGS.

In the light of all the above, the following conclusions seem to be warranted:

(*a*) In the case of any one botanical species the total number of logs used should be at least 300 or 400. While, therefore, the number from each site would depend somewhat upon the number of sites chosen, nevertheless from any one site not less than 12 and preferably 18 logs should be obtained, in addition to others that possess characteristics of an unusual or exceptional nature.

(*b*) In order to make a proper choice, the collector should be one who has tested or else one who has watched the testing of such an amount of full-size timber of the kind under consideration as to have acquired considerable familiarity with its characteristics. Otherwise, in attempting to secure an average he may magnify, in his own mind, certain features while minimizing others of more importance or possibly leaving out of account certain important considerations.

Thus, in one kind of wood the liability to knots may be the chief consideration, whereas in others there may be few knots, and the amount of pitch, the size of the log from which the beam is cut, etc., may have a great influence. On the other hand, he should have either the necessary botanical and dendrological knowledge, or else the aid of a competent botanist and dendrologist. It would seem that an attempt to employ young men whose only training has been on the side of forestry, without first giving them the additional training described above (however detailed may be the specifications), must result in selections more or less unwise and in more or less useless expenditure.

(*c*) The work upon any one kind of lumber should be either all carried on at one station or at least under the entire control of the director of that station.

ORGANIZATION OF THE PRELIMINARY WORK AT ONE STATION.

(1) The director of the station should have one assistant (or more, if needed) who is an expert in testing, and whose entire time is devoted to the work; and also the services of another man who is an expert in botany and dendrology, this latter man probably being employed only a part of the time.

(2) Select for investigation the kinds of lumber which are ordinarily included under one name by the lumber dealers of a number of large

cities. Determine, by visiting the lumber yards of these cities, how many and what botanical species are included under this head. If only a portion of these botanical species are to be included in the investigation, first ascertain and prescribe methods by which they can be easily identified by the engineer, the inspector, and the lumber dealer after they have been sawed and received at the lumber yard.

(3) Having thus fixed upon the botanical species to be investigated, ascertain what are the localities where they are found, giving preference to those from which large quantities of such lumber can be obtained.

(4) In order to secure the proper efficiency, the work at any one station should include the testing, the botanical, the physical, and the microscopic work, and also the discussion of the results obtained upon the wood investigated at that station.

(5) In the case of any one botanical species, the total number of logs used should be at least 300 or 400. While, therefore, the number from each site would depend somewhat upon the number of sites chosen, nevertheless from any one site there should be obtained at least 12, and preferably 18 or more, logs, and care should be taken to secure fair samples. Thus, if the general character is knotty, while some of the best and some of the poorest should be chosen, the selection should in the main represent the average at the site. Besides the above others may be selected having characteristics of an unusual or exceptional nature.

(6) Before proceeding to collect the logs the two assistants should select more or less lumber at the lumber yards and test it in order to make themselves familiar with the general behavior of that kind of lumber and the general effect upon its resisting powers of the prevalent defects. In case it becomes impossible to have these men do the collecting themselves, then those to whom it is to be intrusted should first, as already stated, see a considerable amount of that kind of lumber tested in the laboratory in full-size pieces, in order that they may be able to make their selection from the engineering point of view, paying attention to the important rather than to the unimportant features.

(7) Other details, such as the notes to be made in the field, including the direction and maximum intensity of the prevailing wind, the amount of protection received from neighboring trees, hills, etc., and other climatic conditions, as well as the proper method of sawing the logs, etc., will not be mentioned here.

(5) PLAN FOR THE EXECUTION OF TIMBER TESTS.

The following plan of operation and method of test, partly based on the foregoing plan of Professor Lanza, has been adopted by the Bureau of Forestry, tentatively, as the method of procedure for the proposed timber tests.

The mechanical tests are, with the exception of tests on large columns, to be made at the various stations throughout the country. It is necessary, on account of the large machines needed for the column tests, to confine the latter to one or two stations. The tension test has been omitted from the following programme on account of the difficulty of making it and the minor importance of the result.

In order that the work of the several testing stations may be uniform, standard methods of procedure in the making and recording of tests will be followed.

Notes and observations, both in the field and laboratory, are to be carboned and a carbon copy sent to the Washington laboratory. All machines are to be calibrated.

Special emphasis is to be laid upon the photographic work. Each stick is to be photographed after test on all four sides and on both ends, and copies of these photographs are to be filed in Washington. They will be published as far as necessary in connection with the results of the tests.

No detailed instructions on forms for the work in Series II, III, IV, and V have yet been prepared; the work at present will be limited to Series I. It is hoped, however, that a full discussion of suitable methods for the entire work will follow.

The following programmes and instructions are suggested for discussion for Series I:

Series I.

TESTS ON MARKET TIMBER.

(1) Timber selected, dressed on four sides, and ends squared, described and given a serial number.

(2) Timber delivered.

(3) Timber measured and weighed.

(4) Timber tested according to method for testing large beams, as given below.

(5) Timber photographed.

(6) Disks cut from center and two other points for determining moisture. (For alternate plan see Professor Lanza's method.)

(7) Pieces cut for minor tests and their locations in stick recorded.

(8) These small pieces photographed, measured, tested, and then moisture determined.

LARGE BEAM TESTS.

(1) Measure dimensions of beam and weigh; the weight per cubic foot and specific gravity to be computed from these measurements.

(2) Set scale of beam of testing machine at zero while timber rests on platform. Load, as a rule, to be applied at center.

(3) A rate of increase of load will be decided on. Unless reasons

to the contrary appear, the speed of application of load will be that used in former tests, namely, $\frac{1}{4}$ inch per minute for large beams and $\frac{1}{8}$ inch per minute for small beams, the beam to be kept floating beyond the yield point; maximum load to be recorded. Suitable bearing blocks are to be used to prevent local crushing of timber. Such blocks and small tools are to be furnished by the Washington laboratory to other testing stations in order to insure uniformity.

(4) Trace cracks and describe nature of rupture.

(5) Mark out and stamp the sticks to be taken from beam for minor tests.

(6) Remove beam from machine and photograph.

(7) Cut three disks about 1 inch thick for moisture determinations, one near region of rupture and one from each quarter point; also piece for minor tests.

DETERMINATION OF MOISTURE.

Disk method.—To be determined from three disks, one from region of rupture and one from each quarter point.

(1) Weigh.

(2) Put in hot-air bath at 100° C. and dry to constant weight.

(3) Remove and cool in desiccator.

(4) Weigh again.

(5) Determine per cent of moisture with reference to dry weight and specific gravity.

Professor Lanza's method.—The method for determining moisture suggested by Professor Lanza has already been stated, but a brief summary for comparison may not be out of place here.

(1) Measure and weigh the entire specimen (after fracture).

(2) Dry the entire specimen in the kiln until the percentage of moisture is reduced to a very small amount.

(3) Measure and weigh the entire specimen the second time, thus determining the loss of weight, and also the shrinkage.

(4) Determine the remainder of the moisture by drying suitably chosen disks.

This method, while more complete, is open to the same objections encountered in the disk method. For instance, it is impossible to reduce the percentage of moisture below a certain amount; besides this, neither method takes into account the effect of the volatile oils which are present in almost all species of pine.

The length of time necessary to complete a determination by these methods, as well as the great expense of the second method, is a serious objection to their use.

Proposed method.—As already stated, no account is taken of the quantity of volatile oils that are distilled in the above methods for determining moisture. These oils are included as moisture, and in some cases they amount to as much as 20 or 30 per cent of the moisture

thus determined. The effect of these oils on the strength of timber has not been determined.

The Washington laboratory has outlined a method for determining the moisture and volatile oils which gives promise of being very satisfactory.

In cutting the disks for determining the moisture duplicate disks were taken, the moisture of one set being determined by the disk method and that of the other in the following manner:

The method involves, first, the determination of the total volatile oil, and, second, the determination of the total volatile matter, the difference being the moisture.

For determining the volatile oils the disks are reduced to shavings, 300 to 350 grams (10.5 to 12.3 ounces) of which are placed in a tubular iron retort, which is surrounded by a steam jacket for the purpose of keeping the shavings at 100° C. Through the shavings in this retort is passed a current of steam, and the volatile oils carried off by this current of steam are passed through a condenser and collected in a flask. The volatile oil thus collected is separated from the water and weighed.

For the determination of the total volatile matter, 25 grams of the same sample are at the same time dried in vacuo at 100° C. until the water is driven off, a stream of dry air being passed through the shavings to carry off the volatile matter. From the total volatile matter thus obtained, the volatile oils, as determined by the first process, are deducted, the remainder being the moisture.

Below are given duplicate determinations of the same sample by both the disk and the distillation method. The two disk determinations were made at the same time, and the two by the distillation method were not made within a week of each other.

SAMPLE 4–1–A.

Determinations from disks:

10.73 } Per cent moisture.
11.81 }

Distillation method:

17.73 } Per cent volatile matter.
17.55 }

2.32 } Per cent volatile oils.
2.20 }

15.38 Per cent water.

COLUMN TESTS.

To be outlined.

MINOR TESTS.

Compression—

A. Along grain:

(1) Cut test pieces from uninjured ends of sticks full size and smaller, depending on strength of timber and capacity of testing machine, length

to be at least four diameters. Test at least three specimens from each timber.

(2) Square ends and measure dimensions.

(3) Apply load continuously at rate of —— inches per minute, and read amount of compression on deflectometer until failure occurs.

(4) Describe character of failure.

(5) Determine moisture in test pieces, according to distillation method.

B. Across grain:

(1) Preparation of test pieces. Use 4″x4″x16″. Square, caliper, and weigh. Test three pieces from each stick.

(2) Apply load in full width of block and along 4 inches of length, at speed of —— inches per minute. Determine loads at 3 per cent compression and at 15 per cent compression and maximum load.

(3) Note if failure develops as a result of horizontal shear.

(4) Determine moisture.

(5) Repeat with blocks of varying height until a maximum load is no longer indicated.

Shearing test—

A. Along grain:

The method of making test is under investigation. Suggestions are invited.

(6) INSTRUCTIONS AND FORMS.

Timber Tests.

DESCRIPTION OF MATERIAL.

Series I.

TIMBER FROM THE OPEN MARKET.

Testing station:
Stick number: Laboratory number:
Market name:
Species:
Dimensions:
Obtained from:
History:
Air or kiln dried:
Market grading and standard used:
Imperfections:
Per cent sap:
Rate of growth:
Photographs taken:
Date of purchase:
Remarks:

On the back of each descriptive blank diagrams are printed in which the four sides and ends of the sticks will be sketched, showing the proportion of heart and sap wood, and the knots, checks, or other defects which may occur.

BENDING TEST.

Laboratory: Date of test:
Stick No.: Species:
Mark: Series No.: Lab. No.:
Size: Weight: Moisture, per cent:
Speed of machine (inches per minute): Machine:

Disposition in machine. (Sketch.)

Strength of extreme fiber:
At elastic limit f, lbs. per sq. in.
At maximum load (modulus of rupture), lbs. per sq. in.
where $f = \frac{3\ W1}{2\ bh}\ 2 =$
calculated greatest shearing stress.
Modulus of elasticity = lbs. per sq. in.
Total resilience = inch lbs.
El. res. inch lbs.
Total resilience per cu. in. = inch lbs.
El. res. per cu. in. inch lbs.

Time.	Load.	Readings.				Deflection.	Remarks.

Diagrams of loads and deflections. Operator:

Sketch of failure. Certified to by—

LABORATORY RECORD OF LOG FROM FOREST.

Laboratory: Date:
Log No.: Species: Origin:
Series No.:
Date cut: Date delivered:
Date photographed: Date sawed:
Diagram of sawing:

Record of sticks

CUT FROM LOG.

Stick No. and mark.	Lab. No.	Size.	Weight when sawed.	Kind of test.	Date tested.

Certified to by ——

RECORD OF STICK FROM MARKET.

Laboratory:
Stick No.: Species:
Series No.: Lab. No.:
Locality: Date delivered:
Date photographed:
Tested for: Date:
Diagram of division:

Record table of tests of minor sticks

CUT FROM ABOVE STICK.

Stick No. and mark.	Lab. No.	Size.	Weight when sawed.	Kind of test.	Date tested.

Certified to by ——

COMPRESSION TEST.

Across grain or along grain.

Laboratory: Date:
From stick No.: Species:
Mark: Series No.: Lab. No.:
Size: Weight: Moisture, per cent:
Machine:
Speed of machine:
Disposition in machine: Results:
(Sketch.) Crushing strength—
At 3 per cent distortion ..... lbs. per sq. in.
At 15 per cent distortion ..... lbs. per sq. in.

Time.	Load.		Scale.	Compression.	Remarks.
	Pounds.	*Per square inch.*	*In.*	*Inches per min.*	

Sketch of failure: Operator:

Certified to by—

SHEARING TEST.

Laboratory: Date:
From stick No.: Species:
Mark: Series No.: Lab. No.:
Size: Weight: Moisture, per cent:
Machine:
Disposition in machine and direction of shear (sketch):

Results: Shearing strength in—
Single shear .....lbs. per sq. in.
Double shear .....lbs. per sq. in.

Time.	Load.	Remarks.

Sketch of failure: Operator:

Certified to by—

DETERMINATION OF MOISTURE.

Laboratory: Date:
From stick No.: Species:
Mark: Series No.: Lab. No.:
Size: Weight: Moisture, per cent:
Temp. of oven: Date put in oven:

Date of weighing.	Weight.	Size.

Moisture in per cent:

Certified to by—

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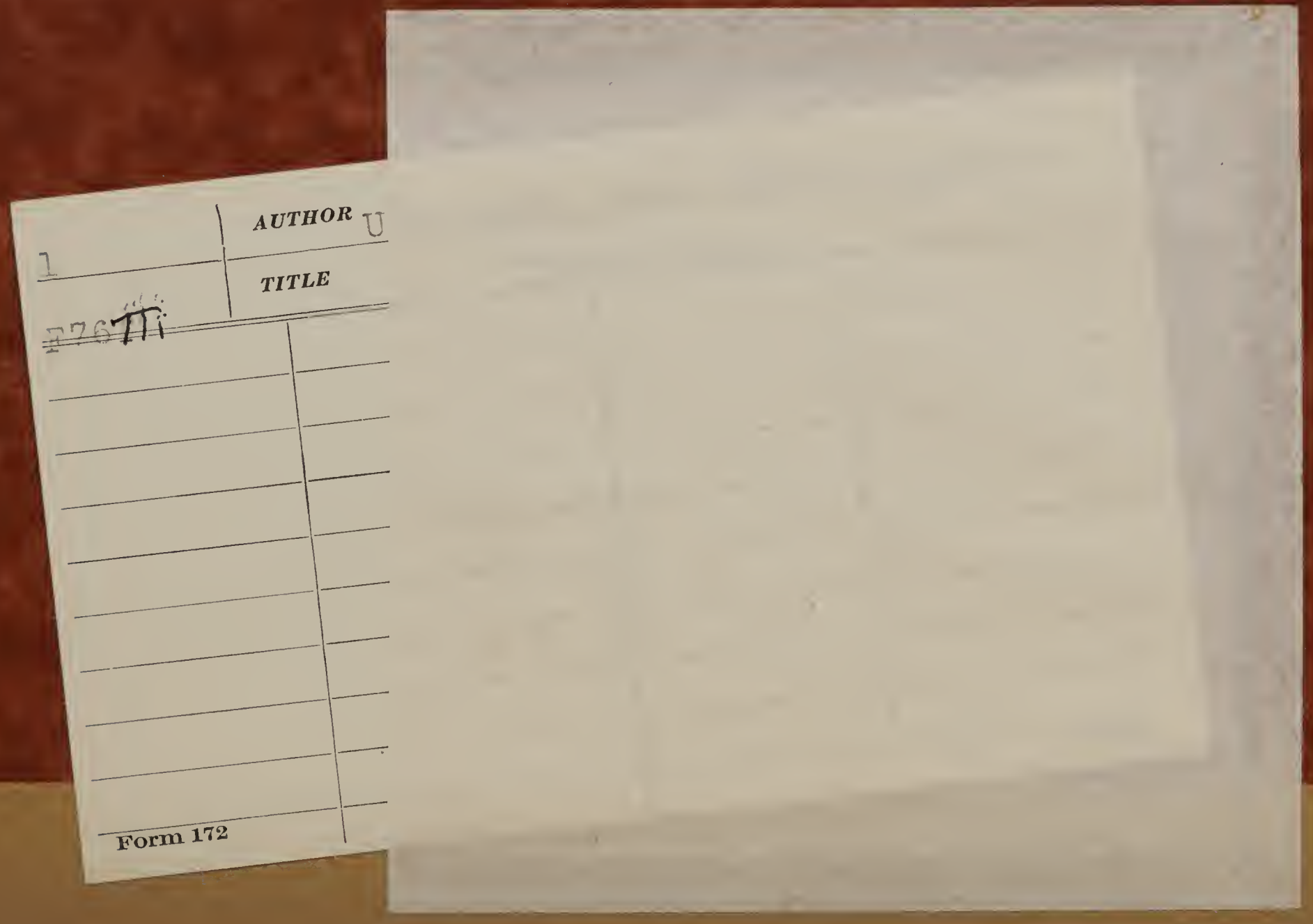
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